CARDIOPULMONARY LIFE SUPPORT SYSTEM

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CLAIMING FOREIGN PRIORITY

The applicant claims and requests a foreign priority, through the Paris Convention for the Protection of Industry Property, based on a utility model application filed in the Republic of Korea (South Korea) with the filing date of September 25, 2001, with the utility model application number 10-2000-0032507, by the applicant. (See the attached declaration)

BACKGROUND OF THE INVENTION

The invention relates to an artificial heart for a patient requiring a cardiopulmonary life support in form of either artificial heart implantation or extracorporeal heart assistance. More specifically, the present invention relates to a cardiopulmonary life support system that substantially prevents blood clotting (thrombus) and dissolution or destruction of red blood cells (hemolysis) from occurring in blood vessels of a heart patient who receives its assistance.

FIG. 1 is a schematic view showing a heart **2**, lungs **4** and a blood circulation in a mammal or a human, wherein arrows indicate direction of the blood circulation. As shown therein,

the heart **2** includes two atriums above and two ventricles below. A main vein **6** is connected to the right atrium and the right ventricle is linked to a pulmonary artery **8**. The lungs are connected to the left atrium and the left ventricle is linked to an aorta **10**. Regular pumping of the left ventricle pushes out blood therein into the aorta **10** to deliver nutrition and oxygen to each capillary vessel in the body. Meanwhile, the blood with less oxygen is in turn collected in the main vein that links to the right atrium to complete a blood circulation known as a systematic circulation. The oxygen-depleted blood collected in the right atrium is released down to the right ventricle and sent to each lung through the pulmonary artery for blood oxygenation. The blood oxygenated in the lungs is released through the left atrium down to the left ventricle. Through the blood circulation for blood oxygenation also known as a pulmonary circulation, the oxygen-depleted blood is converted to an oxygen-rich blood and collected back in the left ventricle. The oxygen-rich blood collected in the left ventricle repeats the systematic circulation in accordance with the regular pumping which generates rhythmic pulses. A valve in each atrium and ventricle serves to prevent a reverse stream.

Each rhythmic pulse in the atriums and ventricles differs depending on age, sex and physical condition. However, the heart pulse frequency for an individual is regular in a

stabilized condition. A standard per-minute heart pulse frequency is known to range about 100 to 140 for infants, 80 to 90 for elementary school kids, 60 to 80 for young and middle aged adults, and 60 to 70 for senior people. Male tends to be less in pulse frequency than female. In general, the smaller the body, the more frequent becomes the heart pulsation for animals. If the body-surface area is larger than the body volume, heat emission becomes further invigorated and thus blood circulation should be faster to complement the loss resulting from the heat emission. For example, the per-minute pulse frequency ranges about 30 to 40 for elephants, 90 to 90 for dogs, 140 to160 for rabbits, and 200 to 300 for rats. The pulse frequency in an artificial heart can be adjusted by controlling the rotation of a motor that drives the artificial heart.

The heart along with lungs is the most crucial organ that allows a living body to maintain its life. However, the heart should remain motionless and emptied in order to conduct a precise surgical heart operation. Therefore, considering the vitality of the heart without which the life does not last more than five minutes, an artificial heart or cardiopulmonary assistance device should be inevitably utilized in such life threatening urgent circumstances as a heart attack, a sepsis related shock, or a myocardium infraction.

Many studies on artificial hearts have been focused on blood pumping which most affects functioning of an artificial heart in a body. The leading conventional arts regarding artificial hearts will be now briefly described focusing each function of blood pumping.

FIG. 2 is a view showing a conventional cardiopulmonary device using a rotary pump. As shown therein the rotary pumping device includes a blood storage, a rotary type pump **12**, an oxygenator **13**, and a flexible tube **14**. The blood storage **11** stores therein a blood from a main vein of a patient. The rotary blood pump **12** serves to transfer the blood from the storage **11** to the oxygenator **13**. The flexible tube **14** links the blood storage **12** and the oxygenator **13**. The flexible blood tube **14** is arc-bent by 90 degrees around the rotary blood pump **12**. A rotation shaft **15** is radially formed from the arc-bent portion of the tube **14** through the center of the rotary pump **12**. A rotation arm **16** is engaged to the rotation shaft **15** and two rotary rollers **17** are rotatably provided to rotate in accordance with the rotation shaft **15**. The rotation of the shaft **15** allows the pump **12** to serve to make a sequential squeezing rotation along the arc-bent portion of the tube **14**. However, the squeezing rotation of the pump **12** fails to generate a stable, pulsatile blood pumping. Further, the excessive pressure for the squeezing rotation tends to easily lead to thrombosis and hemolysis in the oxygenator **13**. Also,

the rotary pump **12** is only usable for about 6 to 8 hours which substantially limits its application to a time taking surgical heart operation.

FIG. 3 shows a schematic cross-sectional view of a conventional centrifugal blood pump **21**. The centrifugal blood pump **21** includes an input port (not shown) to receive blood from a flexible tube (not shown) connected to a right atrium, an output port **22** to release the blood from the blood pump **21**, and an impeller **23** having blades. The rotation speed of the impeller **23** can be adjusted depending on a patient. However, since the blood in the centrifugal blood pump **21** becomes in contact with either the inner surface of the blood bump **21** or mechanical surfaces of the impeller **23**, there may easily occur blood clotting or blood dissolution.

In particular, the damage incurrence on red blood cells or blood platelets due to the blood clotting and dissolution is determined by stress resulting from the blood flow in the pump **21** and by how long the blood has stayed in the pump **21**. Also, the stress due to the blood flow is determined by the rotation speed of the impeller **23** and by the asperity of the mechanical surfaces, thereby increasing possibility of blood damage. The time period in which the blood stays in the centrifugal blood pump **21** is a major factor to consider in the pump design. A shear stress sufficient to affect the blood staying in the pump may lead to thrombosis resulting from

congelation, embolism or fibrin accumulation on the inner surface of the pump. There may also occur blood dissolution or red cell destruction due to a flow separation, a cavitation, or a solution swirl which may be caused by the rotation of the impeller **22**. Therefore, the centrifugal blood pump **21** can be utilized for a limited time period like the rotary blood pump.

FIG. 4 shows a conventional pulsatile blood pump **31**. As shown therein, the pulsatile pump **31** includes a bag tube **32**, a pressure plate **33**, a plate support **34**, a rotation body **35**, and a drive motor **36**. The bag tube **32** is provided with a valve (not shown) at each end thereof. The pressure plate **33** pressurizes the tube **32** for blood transfer. The plate support **34** supports and vertically shuttles the pressure plate **33**. The rotation body **35** is threaded to allow the plate support **34** to make a vertical reciprocal movement.

When the pressure plate **33** the plate support **34** are lowered according to the rotation body **35** driven by the motor **36**, the blood is discharged from the tube **32**, and when raised the blood is supplied into the tube **32**, thereby enabling the pulsatile blood pumping. However, the pulsatile blood pump **31** may cause friction by the contact of the rotation body and the plate support **34** to thereby undermine a stabilized reciprocal movement. Further, the reciprocal rotation of the drive motor **36** that drives the rotation body **35** may increase

pressure for pumping the blood to the oxygenator, thereby incurring thrombosis and hemolysis.

FIG. 5 shows a conventional dual pulsatile blood pump **41**. As shown therein, the pulsatile pump **41** includes input ports **43**, **43'**, output ports **44**, **44'**, input valves **45**, **45'**, and output valves **46**, **46'**. Each valve is formed in a corresponding one of the ports. The pump **41** also includes a pump case **42** that houses therein a spherical body **52**. The spherical body **52** has a groove **50** therearound and a gear **51**. The gear **51** is engaged to a rack **53** attached to an inner wall of the pump case **42**. A rubber membrane **49**, **49'** covers the gear **51**, rack **53** and the groove **50**. A belt **54** is carried in along the groove **50** of the body **52** and around a pulley **57** linked to a motor **56**. A tension applied to the pulley **57** together with the engagement of the gear **51** and the rack **53** enables a shuttling movement of the spherical body **52**, whereby the body **52** makes a horizontal shuttle movement to pump the blood in the blood chamber **48**. The dual pulsatile blood pump **31** substantially decreases thrombosis and hemolysis compared to the rotary pump or other pulsatile pumps. However, the mechanical surfaces are exposed to the blood except for the rubber membranes **49**, **49'** and the input and output ports are also exposed to mechanical surfaces, which may still incur thrombosis and hemolysis. Further, the streamline formation around the input and output ports in the pump chamber **48**, **48'**

may lead to pressure loss which easily results in blood clotting or blood dissolution. In addition, the continued friction and stress may serve to elongate the belt and this makes it difficult to maintain stable pulsation and blood pressure. Also, the conventional dual pulsatile blood pump **41** substantially increases production cost due to mechanical requirements for the shuttle movement of the spherical body **41**.

SUMMARY OF THE INVENTION

The invention is contrived to overcome the conventional disadvantages. Accordingly, an object of the present invention is to provide a cardiopulmonary life support system that substantially prevents blood clotting (thrombosis) and dissolution or destruction of red blood cells (hemolysis) from occurring in blood vessels of a heart patient who receives its assistance.

Another object of the invention is to enable a heart patient to use the life support system for a longer time period in form of either extracorporeal life support or surgical implantation. A further object is to improve portability for an extracorporeal system application and to minimize the size of the life support system to facilitate implantation. A still further object is to realize a rhythmic pulsation substantially equivalent to the systematic pulsation in a

living body.

To achieve the above-described objects, the cardiopulmonary life support system according to the present invention comprises a housing defined by a top side, a bottom, a rear side, and an inner periphery. First and second tubes are adjacent to each other in the housing, and the first and second tubes each have an input port and an output port. An alternating member is attached to the housing and disposed between the first and second tubes. The alternating member alternately squeezes the first and second tubes.

In an embodiment, the life support system further comprises a valve formed in said each input and output port to prevent a reverse stream in the first and second tubes, and an oxygenator connected to the output port of the first tube and the input port of the second tube to convert an oxygen-depleted blood to an oxygen-rich blood.

For a better performance, there may be further provided first and second blood storages. The first blood storage is formed between the oxygenator and the input port of the first tube to temporarily store therein the oxygen-rich blood oxygenated in the oxygenator. The second blood storage is connected to the output port of the second tube to temporarily store therein the oxygen-depleted blood.

In this construction, an initial squeezing of the alternating member on the first tube enables the oxygen-rich

blood to partially pump out from the first tube through the first tube output port. A subsequent squeezing of the alternating member on the second tube enables the oxygen-depleted blood to partially pump out from the second tube through the second output port while a restoration of the first tube to its original shape enables the first tube to suck in as much as pumped out therefrom through the first input port valve. A further subsequent squeezing of the alternating member on the first tube enables the oxygen-rich blood to partially pump out from the first tube through the first output port while a subsequent restoration of the second tube to its original shaft enables the second tube to suck in as much as pumped out therefrom through the second input port valve.

The advantages of the cardiopulmonary life support system according to the present invention are numerous. Initially, the gently alternating reciprocal movement of the alternating member squeezes the first and second tubes sequentially, alternately, gently and efficiently for blood pumping operation so that the oxygenator becomes less pressurized by the repeated blood pumping, thereby substantially decreasing incurrence of blood clotting (thrombosis) and dissolution or destruction of red blood cells (hemolysis), which are known as common side effects to most patients receiving assistance of conventional artificial hearts.

Further, the first and second tubes are formed of a flexible, resilient material and the solid alternating member is operatively provided between the first and second tubes in such a simplified, stabilized construction that the expected life span of the life support system is substantially extended without system replacement. In addition, the alternating member and the first and second tubes are efficiently accommodated within the housing to alternately enable each blood pumping operation for the first and second tube in such a limited space that a significant system size decrease is realized, for example, from a conventional refrigerator size to a palm size in an implantation version of the present invention or to a portable size in an extracorporeal assistance version of the present invention.

Also, the gentle, pulsatile blood pumping operation accomplished within the housing in systematic combination of the flexible blood tubes and the gently alternating solid member generates safe and steady blood pulses substantially similar to those of a natural heart, thereby improving product reliability. More importantly, the artificial blood pumping system adapting the alternately tube-squeezing mechanism requires less elements and further simplifies the overall structure for the blood pumping operation, thereby substantially decreasing production cost, whereby a surgical implantation of the life support system may be realized, for

example, within about one and half times the medical bill charged for a large surgical heart operation.

Although the present invention is briefly summarized, the fuller understanding of the invention can be obtained by the following drawings, detailed description and appended claims.

BRIEF DESCIPTION OF THE DRAWINGS

These and other features, aspects and advantages of the present invention will become better understood with reference to the accompanying drawings, wherein:

FIG. 1 is a schematic view showing a heart, lungs and a blood circulation in a mammal or a human;

FIG. 2 is a structural view showing a conventional cardiopulmonary device using a rotary blood pump;

FIG. 3 is a schematic cross-sectional view of another conventional cardiopulmonary device using a centrifugal blood pump;

FIG. 4 is a structural view showing a further conventional cardiopulmonary device using a pulsatile blood pump;

FIG. 5 is a cross-sectional view showing a still further conventional cardiopulmonary device using a dual pulsatile blood pump;

FIG. 6 is a perspective view showing a cardiopulmonary

life support system according an embodiment of the present invention;

FIG. 7 is a perspective view detailing a blood pump unit in FIG. 6;

FIG. 8 is a cross-sectional front view of the blood pump unit in FIG. 6;

FIG. 9 is a cross-sectional top view of the blood pump unit in FIG. 6;

FIG. 10 is a cross-sectional side view of the blood pump unit in FIG. 6;

FIG. 11 is a schematic structural view of a pump drive unit in FIG. 6;

FIG. 12 is a top view of a link unit in FIG. 11;

FIG. 13 is a cross-sectional view of a male spline in FIG. 6;

FIG. 14 is a cross-sectional front view of the blood pump unit in FIG. 6 according to another embodiment of the present invention;

FIG. 15 is a structural view of a blood pump unit according to another embodiment of the present invention; and

FIG. 16 is a cross-sectional top view of the blood pump unit in FIG. 15.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As shown in FIGS. 6 and 7, a cardiopulmonary life support

system **60** according to an embodiment of present invention includes a support body **62** having a side wall **64**. The support body **62** is selectively provided with handles **66**, **68** and rollers **70** to facilitate portability and to improve mobility of the system **60**. On the side wall **64** are attached first and second blood storages **72**, **74**, a blood pump housing **76**, and an oxygenator **78**, which are linked by ducts **80**, **82**, **84**, **86**, **88**, **90**. In this construction, a general blood stream is sequentially made through the duct **82** to be connected to a main vein of a patient, the second storage **74**, the duct **84**, the second tube **96** in the housing **76**, the duct **90**, the oxygenator **78**, the duct **88**, the first blood storage **72**, the duct **86**, the first tube **94** in the housing **94**, and the duct **80** to be connected to an aorta of the patient. Here, each duct is formed of a flexible material to facilitate blood flowing therethrough.

To see a general arrangement of each element for the life support system **60**, the first blood storage **72** is formed between the oxygenator **78** and the first tube **94** via the ducts **88**, **86** to temporarily store therein an oxygen-rich blood oxygenated in the oxygenator **78**. The second blood storage **74** is connected to the second tube **96** via the duct **84**. The second storage **74** temporarily stores therein an oxygen-depleted blood that flows therein from the main vein via the duct **82**.

When the life support system **60** is applied to a patient

requiring an extracorporeal heart assistance, an oxygen-depleted blood flows in through the duct **82** that is to be connected to a main vein of the patient and is oxygenated in the oxygenator **78**. In accordance with a pumping operation in the housing **76**, the oxygenated, oxygen-rich blood flows out through the duct **80** that is to be connected to an aorta of the patient. The pumping operation in the housing **76** is driven by a motor unit **92** that is adjacent to the housing **76**. The housing **76** is defined by a top side **98**, a bottom side **100**, and an inner periphery **102**.

FIGS. 8, 9 and 10 specify construction of a blood pumping mechanism of the life support system **60**. As shown therein, the first and second tubes **94, 96** are provided adjacent to each other in the housing **76**. The first and second tubes **94, 96** each have an input port **94a, 96a** and an output port **94b, 96b**. An alternating member **104** is disposed between the tubes **94, 96** and attached to the housing **76** so as to alternately squeeze the first and second tubes **94, 96**. That is, the alternating member **104** serves to partially thrust each tube **94, 96** in a sequential or an alternating order in accordance with the motor unit **92** to efficiently control a blood flow in and out of the first and second tubes **94, 96**. Preferably, the alternating member **104** is solid in a spherical shape. The alternating member **104** may be also shaped in a capsule type with a solid formation. The first and second tubes **94, 96** are

linearly aligned and substantially parallel with each other in the housing **78**.

The life support system **60** further comprises valves **106, 108, 110, 112** each of which is a one-way valve to allow a single directional stream therethrough. The valves **106, 108, 110, 112** are sequentially formed in the input and output ports **94a, 94b, 96a, 96b** to prevent a reverse stream in the first and second tubes **94, 96**. So the blood flows into the first tube **94** through the first input port **94a** in which the first input valve **106** that is a one-way valve disposed in the first input port **94a** blocks the reverse stream from the first tube **94**. Also, the blood in the first tube **94** may flow out through the first output port **94b** in which the first output valve **108** that is a one-way valve blocks a possible reverse stream from the duct **80** into the first tube **94**. Likewise, the second input valve **110** in the second input port **96a** prevents a reverse stream from the second tube **96** and the second output valve **112** in the second output port **96b** serves to prevent a reverse stream from the duct **90** linked to the oxygenator **78** into the second tube **96**.

In order to improve efficiency of the sequential pumping operation in the housing **76**, the life support system **60** also includes a tube support **114** that is fitted between each tube **94, 96** and the inner periphery **102** of the housing **76**. The tube support **114** is formed in a solid material and

substantially spaced from the alternating member **104**. At least, each tube portion **116**, **118** that makes direct contacts with the alternating member **104** becomes protected from the tube support **114**. Namely, the solid tube support **114** does not in the least prevent activation of the alternating member **104** but serves to stabilize the pumping operation in the housing **76** despite the flexible characteristic of each tube **94**, **96**. Selectively, the tube support **114** may be formed of either a substantially solid material or a substantially rigid material.

The first and second tubes **94**, **96** are each formed of a flexible material. Further, each tube **94**, **96** may be formed of a polymer known to well harmonize with a mammal body in terms of either a surgical operation or a bodily implantation. Selectively, the first and second tubes **94**, **96** may be formed of silicon. According to such a material characteristic, the first and second tubes **94**, **96** are each elastically, substantially restored to its original shape after being squeezed by the alternating member **104**.

To improve usability of the life support system **60**, the input port **96a** for the second tube **96** and the output port **94b** for the first tube **94** are each formed through the top side **98** of the housing **76**. That is, the output port **94b** of the first tube **94** passes through the top side **98** and the output port **96b** of the second tube **96** passed through the bottom side **100**

of the housing **76**.

Importantly, the alternating member **104** serves to generate an artificial rhythmic pulsation substantially similar to the natural blood pumping in the heart of a living body. Specifically, an initial squeezing of the alternating member **104** on the first tube **94** enables a blood to partially pump out from the first tube **94** through the first tube output port **94b**. A subsequent squeezing of the alternating member **104** on the second tube **96** enables the blood to partially pump out from the second tube **96** through the second tube output port **96b** while a restoration of the first tube **94** to its original shape enables the first tube **94** to suck in as much as pumped out therefrom through the first input port valve **106**. And, a further subsequent squeezing of the alternating member **104** on the first tube **94** enables the blood to partially pump out from the first tube **94** through the first tube output port **94b** while a subsequent restoration of the second tube **96** to its original shaft enables the second tube **96** to suck in as much as pumped out therefrom through the second input port valve **110**.

FIGS. **11**, **12** and **13** each show a mechanism to actuate the alternating member **104**. As shown therein, the life support system **60** further includes a shaft **116** having a top portion **118**, a mid portion **120**, and a bottom portion **122**. The shaft **118** is connected to the motor unit **92** and substantially

parallel to the tubes **94, 96**. The top portion **118** of the shaft **116** is rotatably attached to the top side **98**, the mid portion **120** is fixedly attached to the alternating member **104**, and the bottom portion **122** rotatably passes through the bottom side **100** of the housing **76**, whereby an angular reciprocal rotation of the shaft **116** enables the alternating member **104** to alternately squeeze the first and second tubes **94, 96**.

As shown back in FIG. **10**, a support plate **124** is formed between the alternating member **104** and the mid portion **120** of the shaft **116**. That is, the support plate **124** extends from the mid portion **120** of the shaft **116** fixedly to the alternating member **104**. In order to actuate the shaft **116**, the motor unit **92** includes a motor **126**, a decelerator **128**, first and second gears **130, 132**. The decelerator **126** is connected to the motor **126** to moderate a torque from the motor **126**. The first gear **130** has a base **134** and gear teeth **136**, and the second gear **132** has a base **138** and gear teeth **140**. The first gear base **134** is connected to the decelerator **128**, and the first gear teeth **136** is rotatably connected to the second gear teeth **140** of the second gear **132**. A connecting rod **142** extends from the second gear base **138**.

Meanwhile, male and female splines **144, 146** are detachably provided between the shaft **116** and the connecting rod **142**. That is, the male spline **144** in FIG. **8** is attached to the bottom portion **122** of the shaft **116** and detachably

engaged to the female spline **146**, in FIG. **11**. The female spline **146** is linked to the second gear base **132** via the connecting rod **142**. So the rotational torque generated by the motor **126** and moderated by the decelerator **128** is converted to an angular reciprocal rotation in accordance with the first and second gears **130, 132**. Specifically, the first and second gear teeth **136, 140** are each formed in an arc rack to enable generation of the angular reciprocal rotation. For a reliably detachable engagement between the male and female splines **144, 146**, the matching teeth may be shaped in a safety formation as shown in FIG. **13**. It is recommended that teeth **148** in each spline **144, 146** be formed in an irregular alignment.

The alternating movement of the alternating member **104** is preferably implemented in a horizontal direction between the first and second tubes **94, 96**. The alternating member **104** may be provided in a slanting ellipsoid to realize an alternate diagonal squeezing on the first and second tubes **94, 96** as shown in FIG. **14**.

In FIGS. **15** and **16**, a cardiopulmonary life support system **200** according to another embodiment of the present invention is provided in a decreased formation in size to fit for its surgical implantation. As shown therein, the life support system **200** includes a housing **202**, first and second tubes **204, 206**, an alternating member **208**, a first blood storage **210**, and a second blood storage **212**. Each tube **204, 206** has input

and output ports **204a, 204b, 206a, 206b** each of which sequentially includes valves **212, 214, 216, 218** therein to allow a one-way stream in and out of the tubes **204, 206.**

Also, the first blood storage **210** serves to temporarily store therein an oxygenated blood. The second blood storage **212** temporarily reserves therein an oxygen-depleted blood. Short ducts **220, 222, 224, 226** may be provided depending on requirements. A solid tube support **226** is formed between each tube **204, 206** and an inner periphery **228** of the housing **202** to stabilize the blood pumping operation in accordance with the alternating member **208** which is attached to a shaft **230** via an extension **232.**

In this construction, the angular reciprocal rotation of the shaft **230** enables the alternating member **208** to alternately make a horizontal squeezing on the first and second tubes **204, 206.** Accordingly, the first tube **204** regularly pumps out the oxygen-rich blood through the first output valve **214** into an aorta of a heart patient and concurrently the oxygen-depleted blood in the second tube **206** partially flows out through the second output valve **208** for blood oxygenation. Then, the oxygenated blood flows into the first tube **204** to wait for the squeezing of the alternating member **208.**

The advantages of the cardiopulmonary life support system according to the present invention are numerous. First,

the gently alternating reciprocal movement of the alternating member squeezes the first and second tubes sequentially, alternately, gently and efficiently for blood pumping operation so that the oxygenator becomes less pressurized by the repeated blood pumping, thereby substantially decreasing incurrence of blood clotting (thrombosis) and dissolution or destruction of red blood cells (hemolysis), which are known as common side effects to most patients receiving assistance of conventional artificial hearts.

Second, the first and second tubes are formed of a flexible, resilient material and the solid alternating member is operatively provided between the first and second tubes in such a simplified, stabilized construction that the expected life span of the life support system is substantially extended without system replacement.

Third, the alternating member and the first and second tubes are efficiently accommodated within the housing to alternately enable each blood pumping operation for the first and second tube in such a limited space that a significant system size decrease is realized, for example, from a conventional refrigerator size to a palm size in an implantation version of the present invention or to a portable size in an extracorporeal assistance version of the present invention.

Fourth, the gentle, pulsatile blood pumping operation

accomplished within the housing in systematic combination of the flexible blood tubes and the gently alternating solid member generates safe and steady blood pulses substantially similar to those of a natural heart, thereby improving product reliability.

Fifth, the artificial blood pumping system adapting the alternately tube-squeezing mechanism requires less elements and further simplifies the overall structure for the blood pumping operation, thereby substantially decreasing production cost, whereby a surgical implantation of the life support system may be realized, for example, within about one and half times the medical bill charged for a large surgical heart operation.

Although the invention has been described in considerable detail with reference to certain preferred versions thereof, other versions are possible by converting the aforementioned construction. Therefore, the scope of the invention shall not be limited by the specification specified above and the appended claims.